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(54) **MULTI-CORE OPTICAL FIBRE**

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G02B 6/028 (2006.01)

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USPC **385/124**; 385/100; 385/114; 385/126; 385/127; 385/128

(58) **Field of Classification Search** 385/100, 385/114, 126, 127, 128
See application file for complete search history.

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(57) **ABSTRACT**

A multi-core optical fiber **1**A in which a plurality of cores can easily be identified even in the case where they are symmetrically arranged in its section has seven cores **10** to **16**, a visual recognition marker **20**, and a shared cladding **30** enclosing the seven cores **10** to **16** and the visual recognition marker **20**. The cores **10** to **16** and the visual recognition marker **20** extend along the fiber-axis direction. The respective refractive index of the cores **10** to **16** is higher than the refractive index of the cladding **30**. The refractive index of the visual recognition marker **20** differs from that of the cladding **30**. In the cross-section perpendicular to the fiber-axis, the cores **10** to **16** are arranged such that they have 6-fold rotational symmetry and line symmetry. The visual recognition marker **20** is arranged at a position which breaks such symmetry.

5 Claims, 4 Drawing Sheets

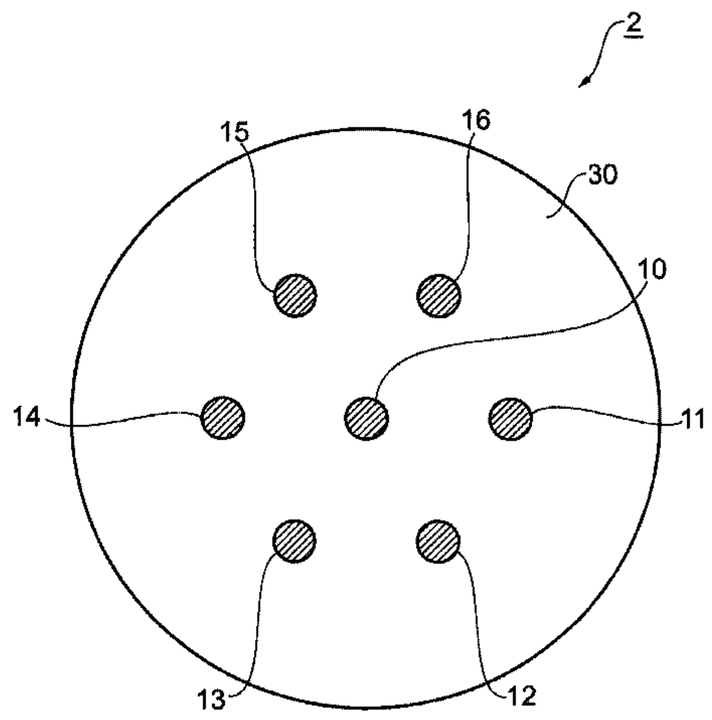


FIG. 1

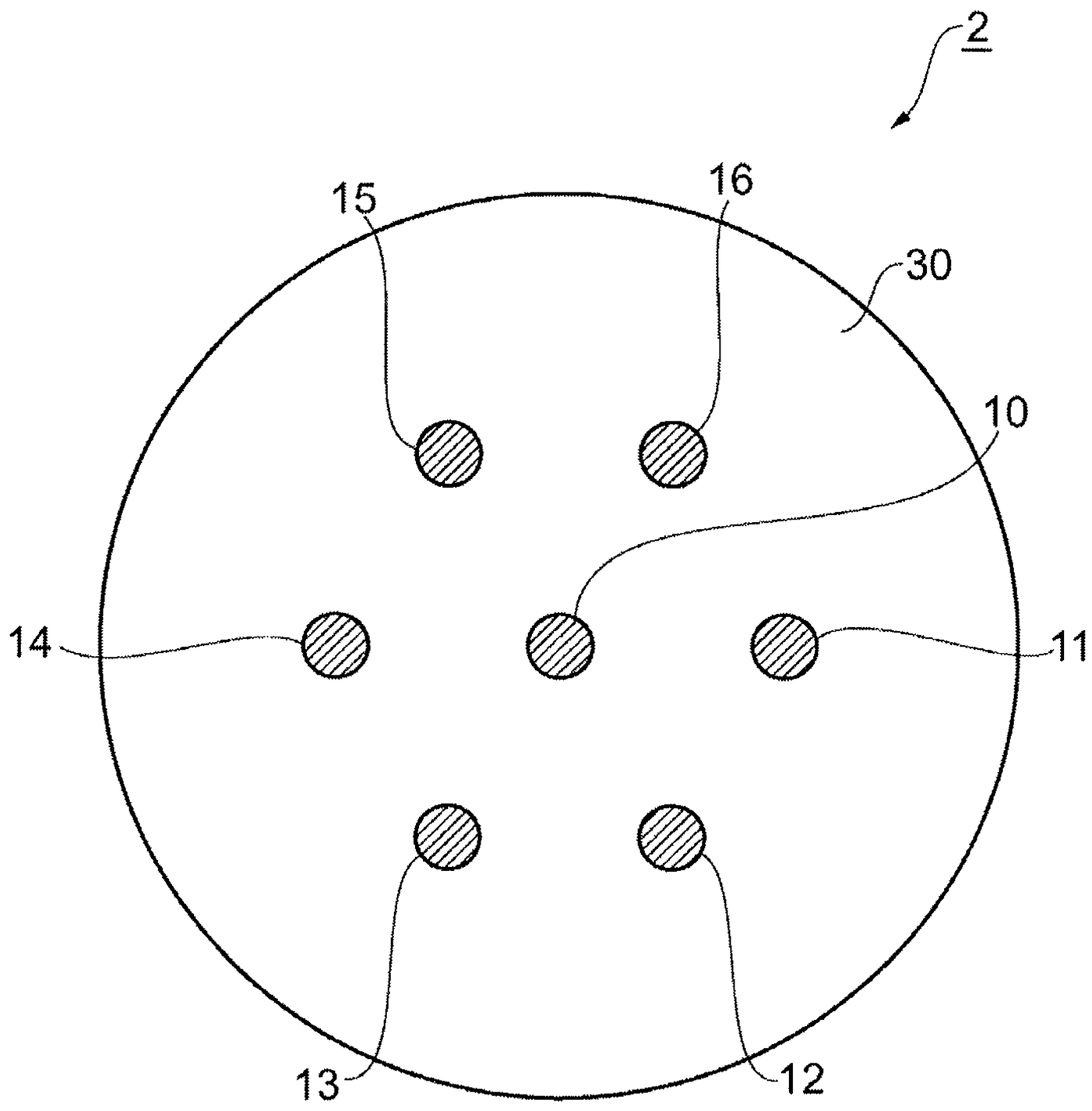


FIG. 2

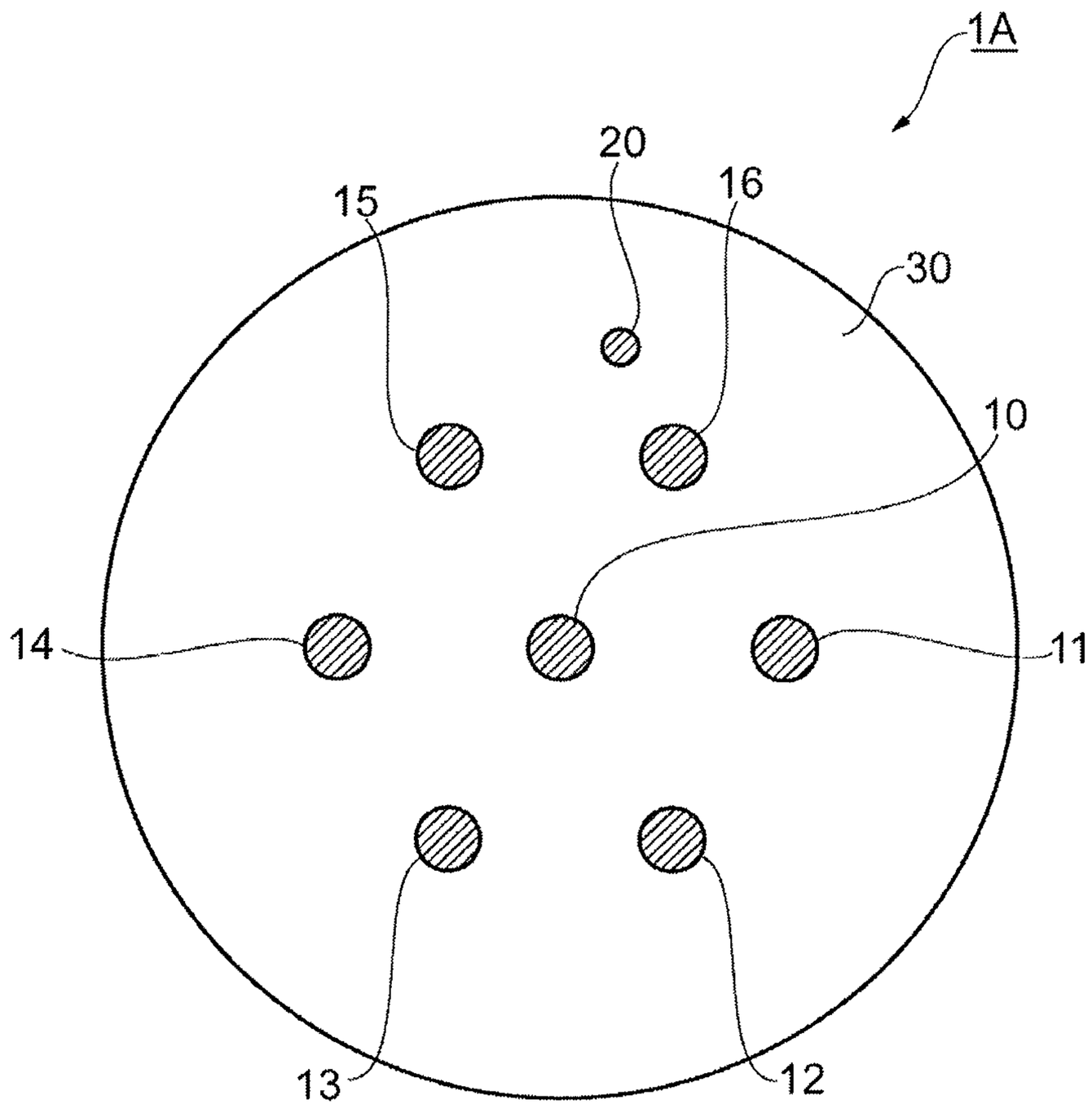


FIG. 3

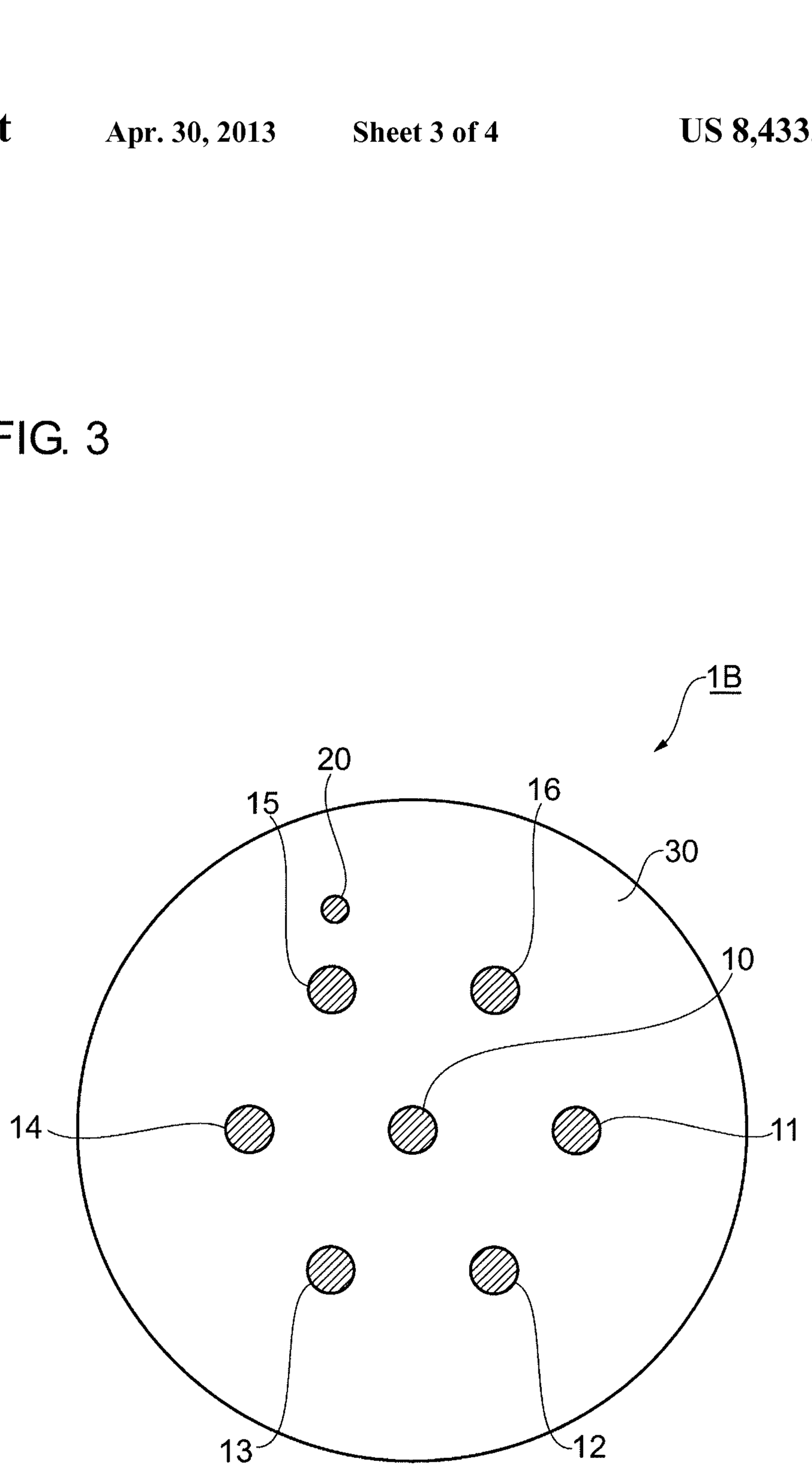
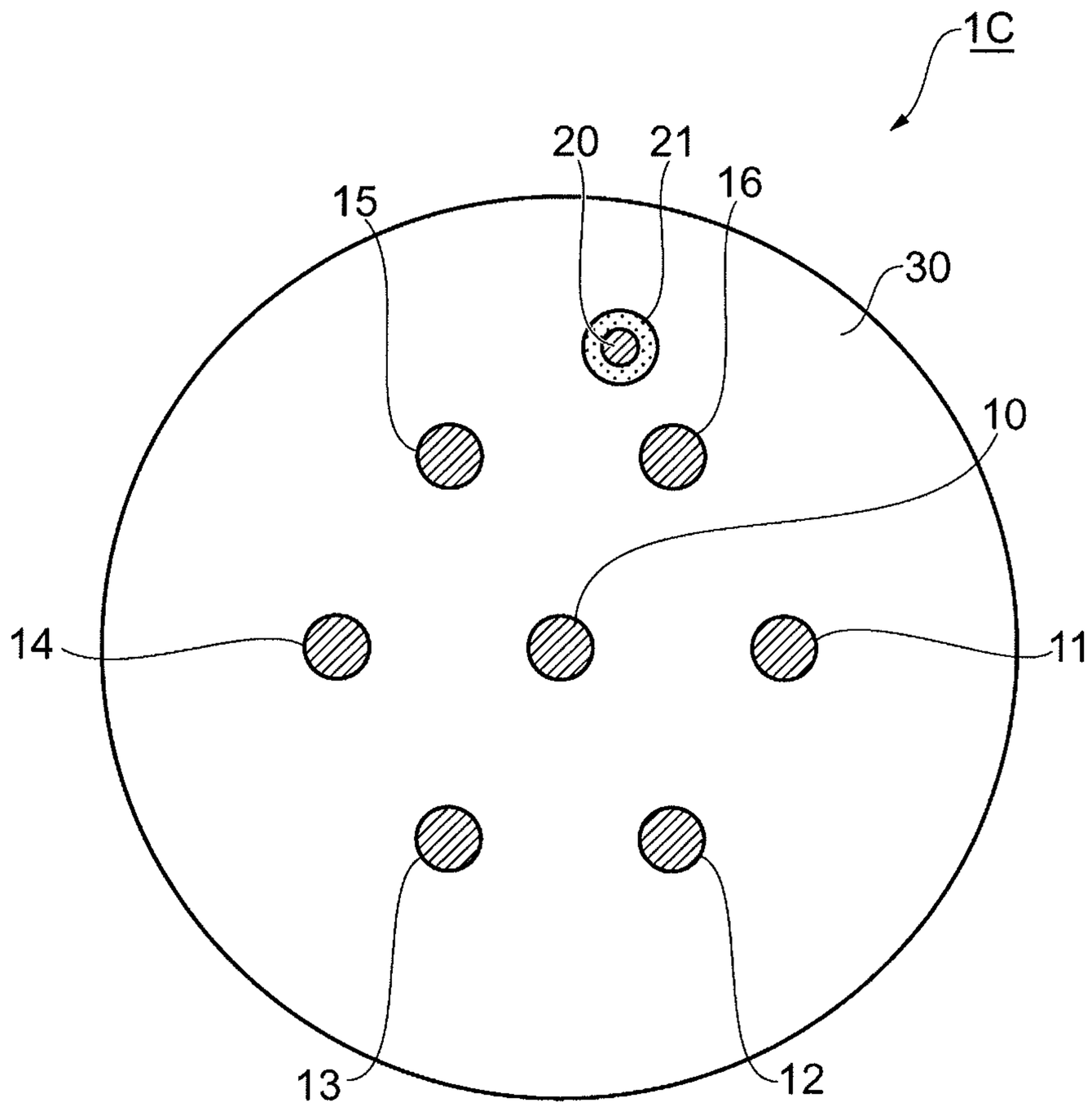


FIG. 4



MULTI-CORE OPTICAL FIBRE

TECHNICAL FIELD

The present invention relates to a multi-core optical fiber in which a plurality of cores extending in a fibre-axis direction and used for transmitting light are covered with a shared cladding.

BACKGROUND ART

The multi-core optical fiber can transmit mass information, since each of the plurality of cores functions as an optically independent optical waveguide. Generally, in the cross-section perpendicular to the fibre-axis of the multi-core optical fibre, two or more cores are arranged in symmetry (rotational symmetry or line symmetry) (Non-patent Literature 1). Symmetrically arranging the plurality of cores makes it possible to arrange the cores with high density in the section of the multi-core optical fibre and to control the cross talk between cores.

FIG. **1** is a cross-section of a multi-core optical fibre **2** for a comparative example. In the multi-core optical fibre **2**, seven cores **10** to **16** which extend along the fibre-axis direction are surrounded by a shared cladding **30**. The core **10** is arranged at the center of the section of the optical fibre **2**, and the six cores **11** to **16** are arranged at equal intervals on the circumference of a circle such that the core **10** is located at the center of the circle. That is, the seven cores **10** to **16** are arranged in a manner having 6-fold rotational symmetry.

In a case where two or more cores are symmetrically disposed in the section, the cores having symmetrical relations cannot be identified. In the multi-core optical fibre **2**, the respective six cores **11** to **16** cannot be identified. Even if the six cores **11** to **16** differ in terms of the core diameter or the refractive index, it would be difficult to identify each of the six cores **11** to **16**.

SUMMARY OF INVENTION

The object of the present invention is to provide a multi-core optical fibre in which each core can easily be identified even if two or more cores are symmetrically arranged in the section of the multi-core optical fibre.

To achieve the object, provided is a multi-core optical fibre having a plurality of cores, a visual recognition marker, and a shared cladding that encloses the plurality of cores and the visual recognition marker, wherein the plurality of cores and the visual recognition marker extend along the fibre-axis direction and the refractive index of the visual recognition marker is different from the refractive index of the cladding, and wherein in the cross-section perpendicular to the fibre-axis the plurality of cores are symmetrically arranged, and the visual recognition marker is arranged at a position that breaks such symmetry.

In the multi-core optical fibre of the present invention, it is preferable that the refractive index of at least a part of the visual recognition marker be higher than the refractive index of the cladding. Preferably, the normalized frequency of the visual recognition marker differs from the normalized frequency of the respective cores by 5% or more. Also, it is preferable that a peripheral part having a refractive index which is lower than the refractive index of the cladding be provided in the periphery of the visual recognition marker.

In the multi-core optical fibre of the present invention, it is easy to discriminate the respective cores since the arrangement of the plurality of cores and the visual recognition marker is not symmetrical as a whole even in the case where the plurality of cores are symmetrically arranged in the section.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cross-section that is perpendicular to the fibre-axis of a multi-core optical fibre for a comparative example.

FIG. **2** is a cross-section that is perpendicular to the fibre-axis of a multi-core optical fibre in Embodiment 1 of the present invention.

FIG. **3** is a cross-section that is perpendicular to the fibre-axis of a multi-core optical fibre in a modified example of Embodiment 1.

FIG. **4** is a cross-section that is perpendicular to the fibre-axis of a multi-core optical fibre in Embodiment 2 of the present invention.

MODE FOR CARRYING OUT THE INVENTION

Hereinafter, preferred embodiments of the present invention will be described in reference to the accompanying drawings. The drawings are provided for the purpose of explaining the embodiments and are not intended to limit the scope of the invention. In the drawings, an identical mark represents the same element so that the repetition of explanation may be omitted. The dimensional ratios in the drawings are not always exact.

FIG. **2** is a cross-section that is perpendicular to the fibre-axis of a multi-core optical fibre **1**A in Embodiment 1 of the present invention. The multi-core optical fibre **1**A has seven cores **10** to **16**, a visual recognition marker **20**, and a shared cladding **30** which encloses the seven cores **10** to **16** and the visual recognition marker **20**. The cores **10** to **16** and the visual recognition marker **20** extend along the fibre-axis direction. The refractive index of each of the cores **10** to **16** is higher than the refractive index of the cladding **30**. The refractive index of the visual recognition marker **20** differs from the refractive index of the cladding **30**. The respective cross-section of the cores **10** to **16** and the visual recognition marker **20** is circular form.

The cores **10** to **16**, the visual recognition marker **20**, and the cladding **30** are respectively made of silica glass as their main element and an additive for adjusting the refractive index is added as needed. For example, the cores **10** to **16** and the visual recognition marker **20** are respectively GeO_2-doped silica glass, and the cladding **30** is pure silica glass. Or, the cores **10** to **16** and the visual recognition marker **20** are respectively pure silica glass, and the cladding **30** is F-doped silica glass, for example. It does not matter whether the core diameter of the cores **10** to **16** is the same or not. Also, it does not matter whether the refractive index of the cores **10** to **16** is the same or not.

In the cross-section perpendicular to the fibre-axis, the core **10** is arranged at the center, and the six cores **11** to **16** are arranged at equal intervals on the circumference of a circle such that the core **10** is disposed at the center of the circle. That is, the seven cores **10** to **16** are arranged in a manner having 6-fold rotational symmetry and line symmetry. The visual recognition marker **20** is arranged at a position that breaks such symmetry. The whole arrangement of the cores **11** to **16** and the visual recognition marker **20** is not symmetrical.

In order to make the whole arrangement of the cores **10** to **16** and the visual recognition marker **20** to be unsymmetrical, the marker **20** may only be arranged such that its distance from any arbitrary two cores of the cores **10** to **16** differs, for

example. Or, as in a cross-section of the multi-core optical fibre **1**B (shown in FIG. **3**), the visual recognition marker **20** may be arranged on a line extending from the line connecting the core **13** and the core **15**. By making such arrangement, the symmetry of cross-sectional structure of the multi-core optical fibre **1**A is lost, and consequently the cores **10** to **16** can easily be discriminated by observing the section and detecting the position of the visual recognition marker **20**.

In order to secure the visibility of the visual recognition marker **20**, it is preferable that the refractive index of at least some region of the visual recognition marker **20** be higher than the refractive index of the cladding **30**. By doing so, light can be propagated through the visual recognition marker **20**, which results in increase of the visibility of the visual recognition marker **20**. Also, in order to restrain the cross talk between the cores **10** to **16** and the visual recognition marker **20**, it is preferable that the normalized frequency of the visual recognition marker **20** differ from the normalized frequency of any of the cores **10** to **16** by 5% or more.

FIG. **4** is a cross-section that is perpendicular to the fibre-axis of a multi-core optical fibre **1**C in Embodiment 2 of the present invention. The multi-core optical fibre **1**C has seven cores **10** to **16**, a visual recognition marker **20**, a shared cladding **30** which surrounds the cores **10** to **16** and the visual recognition marker **20**, and a peripheral part **21** provided in the periphery of the visual recognition marker **20**. The structure of the multi-core optical fibre **1**C is different from that of the multi-core optical fibre **1**A of Embodiment 1 in that the multi-core optical fibre **1**C further includes the peripheral part **21**.

The peripheral part **21** is formed in the periphery of the visual recognition marker **20** and has a refractive index that is lower than the refractive index of the cladding **30**. For example, the cladding **30** is pure silica glass, and the visual recognition marker **20** is GeO_2-doped silica glass, and the peripheral part **21** is F-doped silica glass. In this way, the multi-core optical fibre **1**C is enabled to generate the same effect as the multi-core optical fibre **1**A, and moreover the cross talk between the cores **10** to **16** and the visual recognition marker **20** can be restrained.

The present invention is not limited to the above-mentioned embodiments, and various modifications are possible. For example, the core may be one that transmits light by the photonic band gap instead of the refractive-index difference between the core and the cladding. Also, the number of cores may be arbitrary rather than seven. The symmetry in the arrangement of cores in the section may be 4-fold symmetry instead of 6-fold symmetry. A plurality of visual recognition markers may be provided instead of one visual recognition marker.

INDUSTRIAL APPLICABILITY

With the multi-core optical fibre of the present invention, it is possible to identify a plurality of cores easily and correctly when wiring a multi-core optical fibre or connecting multi-core optical fibres with each other.

PRIOR ART LITERATURE

Non-Patent Literature

Non-patent literature 1: Katsunori Imamura, Kazunori Mukasa, Yu Mimura, Takeshi Yagi, "Multi-core holey fibers for the long-distance (>100 km) ultra large capacity transmission," OSA/OFC/NFOEC2009, OTuC3.

The invention claimed is:

1. A multi-core optical fibre having a plurality of cores, a visual recognition marker, and a shared cladding enclosing the plurality of cores and the visual recognition marker, wherein

the plurality of cores and the visual recognition marker extend along the fibre-axis direction,

the refractive index of the visual recognition marker is different from the refractive index of the cladding, and wherein

in the cross-section perpendicular to the fibre-axis, the plurality of cores are symmetrically arranged, and the visual recognition marker is arranged at a position that breaks such symmetry.

2. A multi-core optical fibre as set forth in claim **1**, wherein the refractive index of at least a part of the visual recognition marker is higher than the refractive index of the cladding.

3. A multi-core optical fibre as set forth in claim **2**, wherein the normalized frequency of the visual recognition marker differs from the normalized frequency of the respective cores by 5% or more.

4. A multi-core optical fibre as set forth in claim **2**, wherein a peripheral part having a refractive index lower than the refractive index of the cladding is provided in the periphery of the visual recognition marker.

5. A multi-core optical fibre as set forth in claim **3**, wherein a peripheral part having a refractive index lower than the refractive index of the cladding is provided in the periphery of the visual recognition marker.

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